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Research conducted under AFOSR grant no. F49620-97-1-0261 focused on exploring the properties of microdischarge devices fabricated in silicon. Cylindrical devices having diameters between 20 μm and 400 μm have been fabricated and intense emission on the B $\rightarrow$ X transition of xenon monoiodide (XeI) in the ultraviolet (UV) is produced when mixtures of Xe/I_2 are introduced to the discharge. Having specific power loadings beyond 100 kW-cm^{-3} *on a continuous basis*, these devices represent a new realm of discharge operation and are attractive candidates as lamps or for the decomposition of environmentally hazardous gases.

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FINAL TECHNICAL REPORT FOR AFOSR GRANT # F49620-97-1-0261

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SUMMARY

Under grant no. F49620-97-1-0261, AFOSR supported a research program focused on microdischarge devices fabricated in silicon. This six month program was quite successful, resulting in a demonstration of the continuous excitation of rare gas halide (XeI) and rare gas oxide excimers in a 400 μm diameter device. Also, "trench" devices and cylindrical devices having diameters as small as 20 μm have been fabricated and operated. As a result of these developments, a patent application was filed in May of 1997.

RESEARCH ACCOMPLISHMENTS

The primary accomplishment realized during the six month period of this grant was the demonstration of the continuous excitation of excimer molecules (rare gas-halide and rare gas-oxide) in a Si microdischarge device. This is an exciting result that was made possible by the unusual properties of these sub-mm diameter, cylindrical discharges.

The construction and basic characteristics of Si microdischarge devices were discussed in the Final Report for AFOSR grant #F49620-95-1-0238 that was recently submitted to AFOSR and so will not be described in detail here. Briefly, cylindrical cavities < 500 μm in diameter and 2-5 mm in depth are micromachined in metallurgical or VLSI grade Si and electrical contacts are made to both upper and lower surfaces. When the device is evacuated and back-filled with a gas, an intense discharge can readily be produced in the device. Because of their small diameters, these devices can be continuously operated at pressures considerably higher than those accessible to conventional devices. Neon discharges, for example, have been operated at pressures above 600 Torr and N_2 pressures exceeding 1 atm have been demonstrated successfully. Of greater importance for excimer species such as the rare gas-halides, however, is the fact that the power loading of these discharges can easily exceed several kW-cm^{-3}, again on a continuous basis.

Rare Gas-Halide Emission

Intense emission in the UV is obtained when Si microdischarge devices are operated with rare gas/halogen precursor gas mixtures. For example, Fig. 1 shows the fluorescence spectrum recorded for a microdischarge in 50 Torr Xe and ~1 Torr I_2 at a current of 3.8 mA. Notice that essentially no visible emission is produced (the feature at ~515 nm is simply the 255 nm peak in second order of the spectrometer grating). In fact, virtually all of the fluorescence lies between ~250 and 350 nm and the most prominent feature is the B $\rightarrow$ X band of xenon monoiodide (XeI) that peaks at 254 nm. This particular excimer was chosen because the B $\rightarrow$ X band coincides almost perfectly with the well-known 6p $^3P_1 \rightarrow$ 6s $^1S_0$ line of atomic Hg at 254 nm. This is

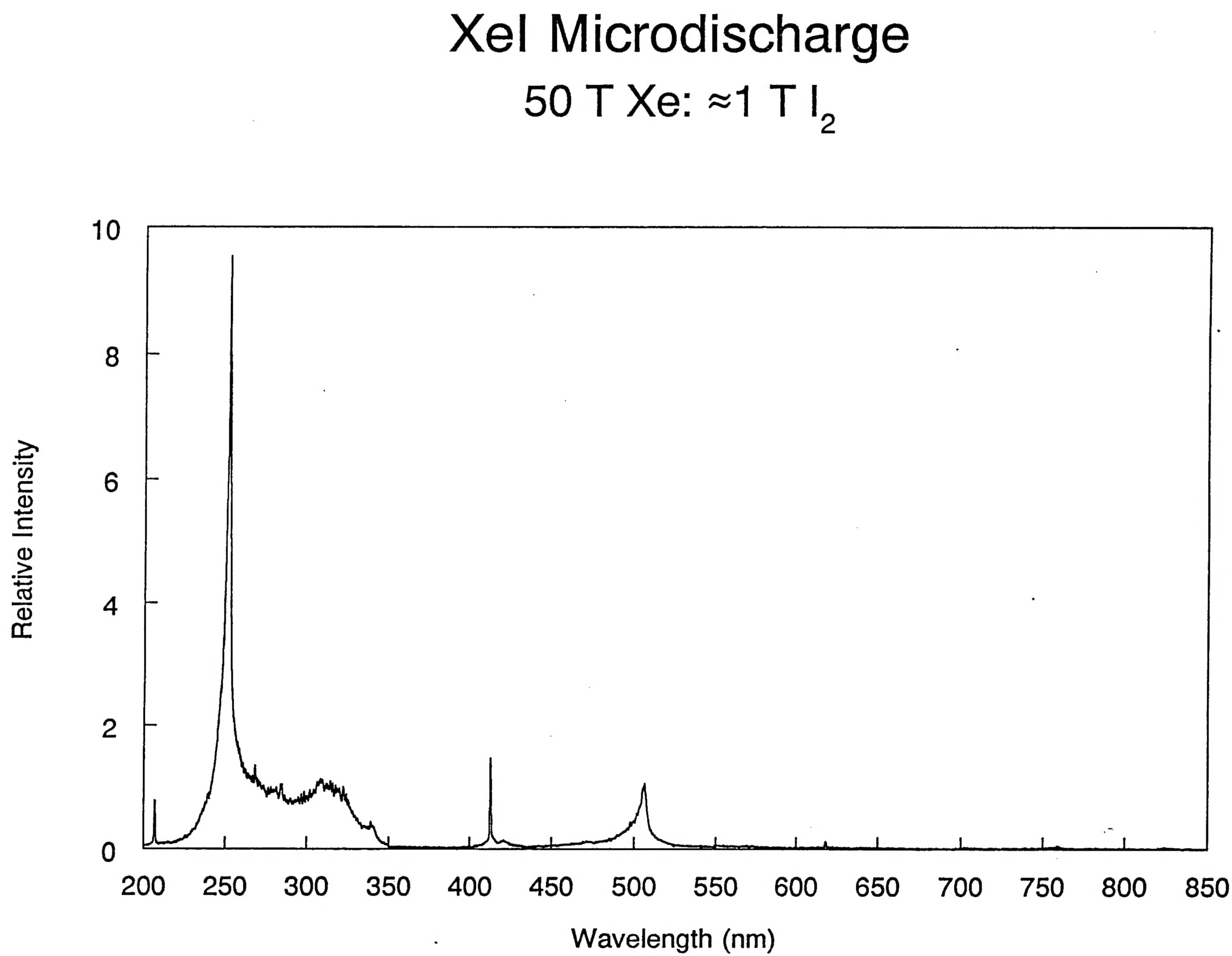

Fig. 1 Emission spectrum for 50 Torr Xe/~1 Torr I_2 gas mixture in a 400 μm diameter microdischarge.

illustrated in Fig. 2 which compares the XeI emission with the fluorescence produced by a low pressure Hg lamp. We believe this miniature UV source to be an extremely attractive candidate for replacing the Hg lamp in several applications such as polymer curing and germicidal applications. Since the XeI emission coincides in wavelength with the Hg 253.7 nm line, the microdischarge can be directly substituted for Hg in lighting applications because no adjustments in the phosphor need be made. Furthermore, Xe and I_2 are non-toxic and are, therefore, vastly preferable to Hg which is of increasing environmental concern.

When the partial pressure of the rare gas is lowered, the microdischarge produces strong emission on the $D' \rightarrow A'$ of I_2 at 342 nm as shown in Fig. 3. Although we have not yet had the opportunity to explore this, we expect to be able to produce emission on the rare gas chlorides, XeCl, KrCl and ArCl, without etching the silicon device significantly. The experiments to date with rare gas/I_2 mixtures show no noticeable etching or sputtering of Si which suggests that long-lived devices are, indeed, feasible.

Rare Gas-Oxide Experiments

XeO ($2\ ^3\Pi \rightarrow 1\ ^3\Pi$) emission has also been produced in Xe/O_2 gas mixtures. This band peaks at ~238 nm and arises from bound $\rightarrow$ free transitions of the molecule for which the upper state is an ion pair state. Again, we note that producing CW emission from these species is only possible because of the high operating pressures and specific power loadings available with these miniature devices.

Conclusions

The six month period covered by this AFOSR grant has witnessed considerable progress in developing microdischarge devices. Specifically, rare gas-halide, I_2 and rare gas-oxide excimer emission has been produced on a *continuous* basis on 400 μm diameter devices at specific power loadings exceeding 10 kW-cm^{-3}. In the near future, we will explore other excimers and extending the lifetimes of these devices by incorporating poly-Si electrodes into the design. We have also recently succeeded in fabricating "trench" devices and cylindrical discharge devices having diameters as small as 20 μm. The latter operated at currents as high as 9 mA and a specific power loading approaching 1 MW-cm^{-3}! This parameter region is unprecedented for a CW discharge and suggests an entirely new realm of discharge physics and applications. We are now focusing our efforts on developing lithographic processes for reproducibly fabricating these devices on a larger scale.

XeI MICRODISCHARGE

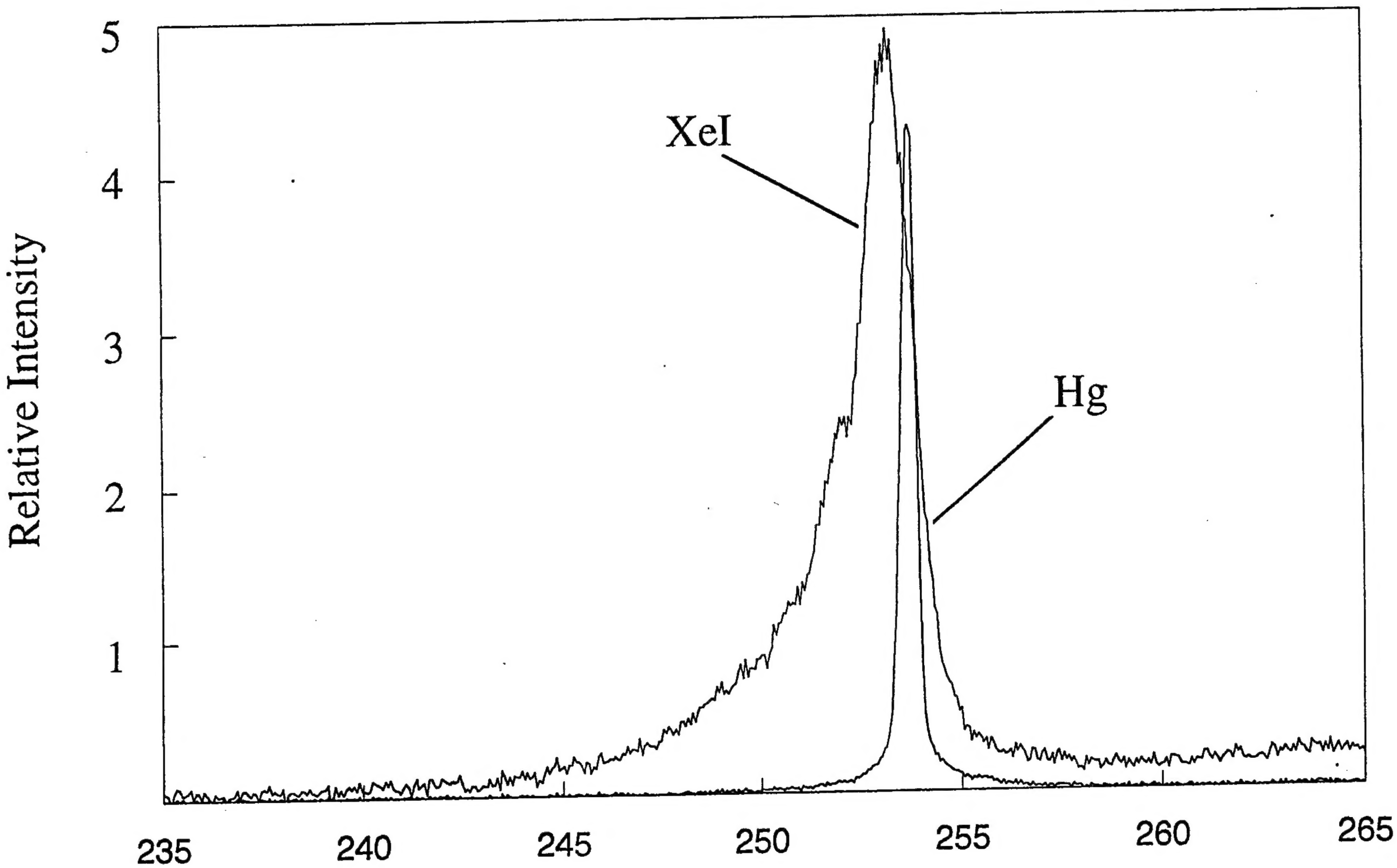

Fig. 2 Expanded view of the B $\rightarrow$ X band of XeI generated by the microdischarge. The position of the Hg resonance line at 253.7 nm is shown for comparison.

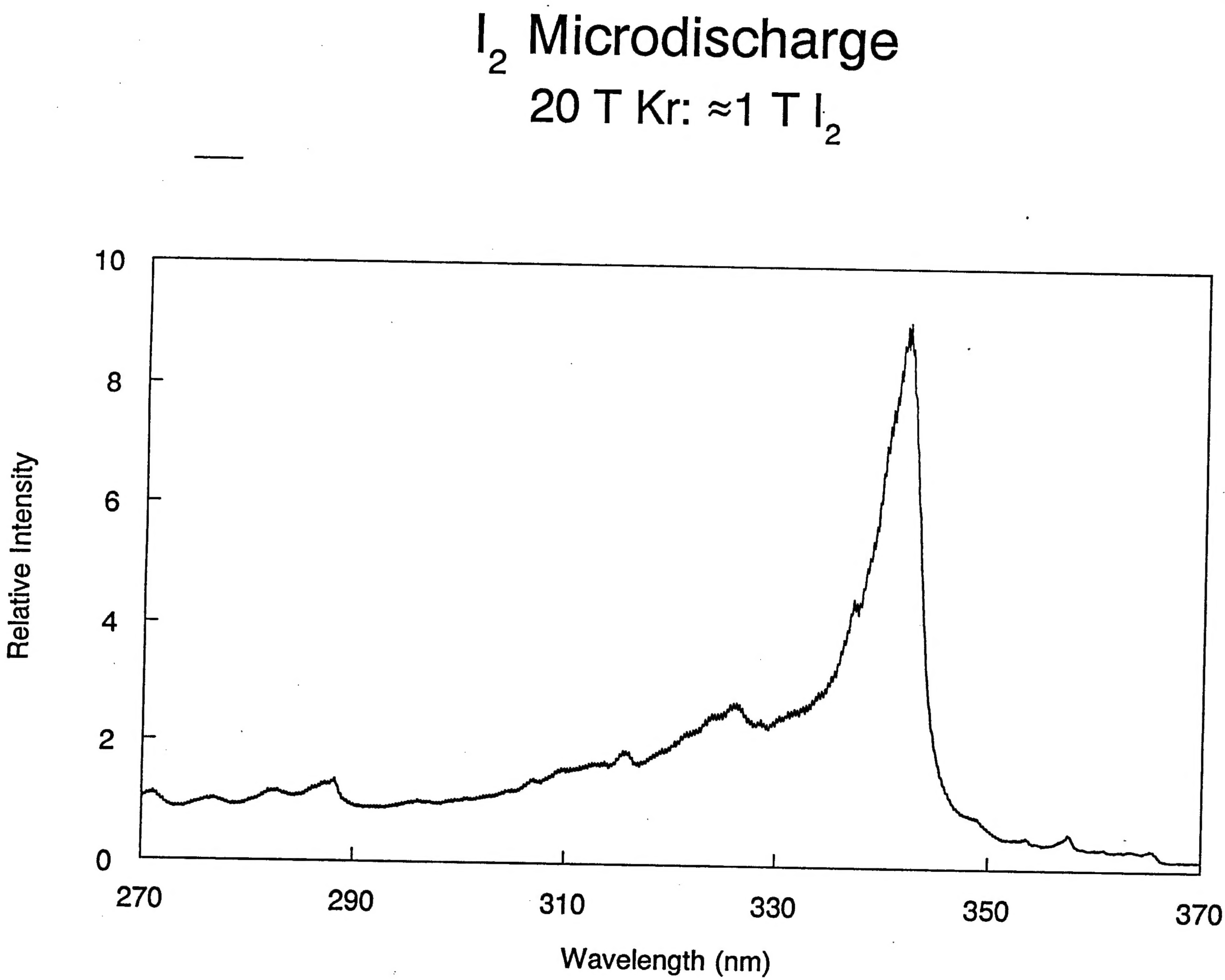

Fig. 3 Fluorescence spectrum in the mid-UV produced in a 15 Torr Kr/1 Torr I_2 gas mixture. Virtually all of the emission is produced by the $D' \rightarrow A'$ transition of I_2.